IN THE CLAIMS

What is claimed is:

1-7. (Canceled)

8. (Currently Amended) A method in image guided radiosurgery for aligning the position of a treatment target relative to a radiosurgical beam generator during treatment, the method comprising:

a. generating a pre-treatment 3D scan showing [[the]]an initial position of said target at treatment planning time;

b. generating a set of 2D reconstructed images from said 3D scan, wherein the set of 2D reconstructed images corresponds to perturbations from said initial position along fewer than six degrees of freedom;

c. generating at near real time one or more 2D x-ray images of said target, wherein said x-ray images show [[the]]a current position of said target at a current time during treatment;

d. registering said reconstructed images with said x-ray images by computing a set of 3D transformation parameters that represent the change in position of said target between said 3D scan and said x-ray images, wherein said 3D transformation parameters are 3D rigid body transformation parameters, and wherein said 3D transformation parameters are represented by three translations and three rotations (x, y, z, r, p, w); wherein x, y, z represent the translations of said target in the directions of three mutually orthogonal axes, respectively, and wherein $r, p,$ w represent three rotations (roll, pitch, yaw) about said three orthogonal axes; and

e. in near real time, adjusting the relative position of said radiosurgical beam generator [[and]]<u>to</u> said target by the amount prescribed by said 3D transformation parameters computed in step d, wherein said target is allowed six degrees of freedom of position.

9. (Previously presented) A method in accordance with claim 8, wherein said x-ray images generated in step c comprises x-ray projection images that represent at least two orthogonal projections A and B of said target onto respective projection image planes, said x-ray projection images being formed by transmitting at least two x-ray imaging beams through said target and onto said respective image planes, wherein each imaging beam is received by a respective x-ray camera after passing through said target.

10. (Original) A method in accordance with claim 9, wherein step b of generating reconstructed images comprises generating two sets of reconstructed images, one set for each of said projections A and B.

11. (Original) A method in accordance with claim 10, wherein step d of registering said reconstructed images with said x-ray images comprises:

A. individually registering each x-ray projection image A and B with their respective set of reconstructed images, by determining a separate set of transformation parameters for each projection x-ray image; and

B. combining the resulting parameters for each projection to obtain said 3D transformation parameters.

12. (Original) A method in accordance with claim 11, wherein said transformation parameters for each of said projections A and B are described by two out-of-plane rotational parameters (r_A, φ_A) and (r_B, φ_B) respectively, and by three in-plane transformation parameters (x_A, y_A, θ_A) and (x_B, y_B, θ_B), respectively.

13. (Currently Amended) A method in accordance with claim 12, wherein said 2D reconstructed images are digitally reconstructed radiographs (DRRs), and wherein step b of generating said 2D reconstructed images comprises:

i) for each projection, specifying a set of rotation angles for each of said out-of-plane rotation parameters r and φ, N_r being the number of rotation angles for rotation parameter r, and Nφ being the number of rotation angles for rotation parameter φ; and

ii) generating two sets of DRRs, one set for each of said projections A and B[[;]], wherein each set includes DRRs that correspond to different combinations of said out-of-plane rotation angles, so that the number of DRRs in each set is N_r*N_φ.

14. (Original) A method in accordance with claim 13, wherein the step of generating 2D reconstructed images further comprises the step of computing a set of in-plane rotated DRR images by performing a plurality of in-plane rotations on said DRRs, thereby creating a set of in-plane rotated reference DRRs for each projection.

15. (Original) A method in accordance with claim 14, wherein said step of creating reference DRRs is performed offline.

16. (Currently Amended) A method in accordance with claim 9, wherein the step of computing said 3D transformation parameters comprises:

i) individually computing the transformation parameters $(x_{A}, y_{A}, \theta_{A})$ and $(x_{B}, y_{B}, \theta_{B})$ for each projection image A and B; and

ii) combining the transformation parameters for projection A with the transformation parameters for projection B so as to obtain said 3D transformation parameters[[;]], and wherein said 3D transformation parameters are represented by three translations and three rotations (x, y, z, r, p, w).

17. (Original) A method in accordance with claim 16, wherein said 3D transformation parameters are related to the transformation parameters for projections A and B by the following relationship:

$x = (x_A + x_B) / 2$, $y = (y_A - y_B) / \sqrt{2}$, $z = (y_A + y_B) / \sqrt{2}$,

$r = (r_A + r_B) / 2$, $p = (\theta_B - \theta_A) / \sqrt{2}$, $w = (\theta_B + \theta_A) / \sqrt{2}$.

18. (Currently Amended) method in image guided radiosurgery for aligning the position of a treatment target relative to a radiosurgical beam generator during treatment, the method comprising:

a. generating a pre-treatment 3D scan showing [[the]]an initial position of said target at treatment planning time;

b. generating a set of 2D reconstructed images from said 3D scan, wherein the set of 2D reconstructed images corresponds to perturbations from said initial position along fewer than six degrees of freedom;

c. generating at near real time one or more 2D x-ray images of said target, wherein said x-ray images show [[the]]a current position of said target at a current time during treatment, wherein said x-ray images comprise x-ray projection images that represent at least two orthogonal projections A and B of said target onto respective projection image planes,

said x-ray projection images being formed by transmitting at least two x-ray imaging beams through said target and onto said respective image planes, wherein each imaging beam is received by a respective x-ray camera after passing through said target;

d. registering said reconstructed images with said x-ray images by computing a set of 3D transformation parameters that represent the change in position of said target between said 3D scan and said x-ray images, wherein computing said 3D transformation parameters comprises:

individually computing the transformation parameters $(x_{A}, y_{A}, \theta_{A})$ and $(x_{B}, y_{B}, \theta_{B})$ for each projection image A and B, wherein computing the transformation parameters for each projection comprises:

i) computing [[the]] in-plane transformation parameters using [[said]] in-plane rotated reference digitally reconstructed radiographs (DRRs); and thereafter

ii) estimating [[the]] out-of-plane rotation parameters using the in-plane transformation parameters computed in step i) above; and thereafter

iii) iteratively refining said in-plane and out-of-plane transformation parameters, until said parameters converge to a sufficient accuracy; and

combining the transformation parameters for projection A with the transformation parameters for projection B so as to obtain said 3D transformation parameters; and wherein said 3D transformation parameters are represented by three translations and three rotations (x, y, z, r, p, w); and

e. in near real time, adjusting the relative position of said radiosurgical beam generator [[and]]to said target by the amount prescribed by said 3D transformation parameters computed in step d, wherein said target is allowed six degrees of freedom of position.

19. (Original) A method according to claim 18, wherein step i) is performed using 3D multi-level matching, and a sum of absolute difference similarity measure.

20. (Original) A method according to claim 18, wherein step ii) is performed using a 1D search and a pattern intensity similarity measure.

21. (Original) A method according to claim 20, wherein step iii) comprises:

a) refining the in-plane translation parameters x and y using 2-D sub-pixel matching; and thereafter

b) refining the in-plane rotation parameter using 1-D interpolation.

22. (Previously presented) A method in accordance with claim 18 wherein said 3D scan comprises at least one of: a CT scan, an MRI scan, an ultrasound scan, and a PET scan.

23. (Currently Amended) An image guided radiosurgical system for radiosurgical treatment of a target, the system comprising:

a. means for providing pre-treatment 3D scan data <u>showing an initial position </u>of said target;

b. a radiosurgical beam generator for generating at least one radiosurgical beam;

c. imaging means for generating one or more 2D x-ray images <u>showing a current position </u>of said target in near real time, said imaging means including:

i) an imaging beam source for generating at least one imaging beam having a known intensity, and having a known position and angle relative to said target; and

ii) means for directing said imaging beam towards and through said target from said known location and angle, and at said known intensity;

iii) at least one image receiver for detecting the attenuated imaging beam after said beam has passed through said target; and

iv) an image processor for processing data from said image receiver to generate said x-ray image;

d. a controller, including:

i) means for generating ~~at least one~~ a set of reconstructed 2D images of said target, based on said 3D scan data, and using said known intensity, location, and angle of said imaging beam, wherein the set of reconstructed 2D images corresponds to perturbations from said initial position along fewer than six degrees of freedom;

ii) registration means for registering said reconstructed 2D image with said near real time x-ray image, said registration means including means for computing a set of 3D transformation parameters that represent the change in position of said target between said 3D scan and said near real time x-ray image, wherein said 3D transformation parameters are 3D rigid body transformation parameters, and wherein said 3D transformation parameters are represented by three translations and three rotations (x, y, z, r, p, w), wherein x, y, z represent the translations of said target in the directions of three mutually orthogonal axes, respectively, and wherein r, p, w represent three rotations (roll, pitch, yaw) about said three orthogonal axes; and

e. positioning means, responsive to said controller, for adjusting in near real time the relative position of said radiosurgical beam generator [[and]]to said target by the amount prescribed by said 3D transformation parameters.

24. (Currently Amended) A system in accordance with claim 23, wherein said [[2D]] reconstructed <u>2D</u> images comprise[[s]] digitally reconstructed radiographs (DRRs).

25. (Original) A system in accordance with claim 23, wherein said 3D scan data comprise at least one of CT scan data, MRI scan data, and PET scan data.

26. (Original) A system in accordance with claim 23, wherein said one or more 2D x-ray images of said target comprise x-ray projection images that represent at least two orthogonal projections A and B of said target onto respective projection image planes, and wherein said x-ray projection images are formed by transmitting at least two x-ray imaging beams through said target and onto said respective image planes, wherein each imaging beam is received by a respective x-ray camera after passing through said target.

27. (Original) A system in accordance with claim 23, wherein said means for generating at least one reconstructed 2D image comprises means for generating two sets of reconstructed images, one set for each of said projections A and B.

28. (Original) A system in accordance with claim 23, wherein said registration means comprises:

A. means for individually registering each x-ray projection image A and B with their respective set of reconstructed images by determining a separate set of transformation parameters for each projection x-ray image; and

B. combining the resulting parameters for each projection to obtain said 3D transformation parameters.

29. (Original) A system in accordance with claim 28, wherein said transformation parameters for each of said projections A and B are described by two out-of-plane rotational parameters (r_A, φ_A) and (r_B, φ_B) respectively, and by three in-plane transformation parameters (x_A, y_A, θ_A) and (x_B, y_B, θ_B), respectively.

30. (Previously Presented) A system in accordance with claim 29, wherein said means for generating at least one reconstructed 2D image of said target comprises:

i) means for specifying, for each projection A and B, a set of rotation angles for each of said out-of-plane rotation parameters r and φ, wherein the number of rotation angles for rotation parameter r is Nr, and the number of rotation angles for rotation parameter φ is Nφ; and

ii) means for generating two sets of digitally reconstructed radiographs (DRRs), one set for each of said projections A and B;

wherein each set includes DRRs that correspond to different combinations of said out-of-plane rotation angles, so that the number of DRRs in each set is N_r*N_φ.

31. (New) The method of claim 8, wherein the set of 2D reconstructed images includes a first set of 2D reconstructed images that corresponds to out-of-plane rotations for a first plane of a first x-ray image and a second set of 2D reconstructed images that corresponds to out-of-plane rotations for a second plane of a second x-ray image.

32. (New) The method of claim 31, wherein one of the out-of-plane rotations for the first plane is an in-plane rotation for the second plane.

33. (New) A method of image registration, comprising:

generating a pre-treatment 3D scan showing an initial position of a target at treatment planning time;

generating a first set of 2D images and a second set of 2D images from said pre-treatment 3D scan of said target prior to treatment, wherein each of the first set of 2D images and the second set of 2D images correspond to perturbations from said initial position along fewer than six degrees of freedom;

generating a first x-ray image and a second x-ray image of the target to show a current position of said target during treatment;

registering the first x-ray image with the first set of 2D images by computing a first set of transformation parameters;

registering the second x-ray image with the second set of 2D images by computing a second set of transformation parameters; and

combining the first set of transformation parameters and the second set of transformation parameters to obtain a combined set of six 3D transformation parameters that represents a change between the initial position and the current position of the target.

34. (New) The method of claim 33, wherein the first set of transformation parameters include five transformation parameters and the second set of transformation parameters include five transformation parameters.

35. (New) The method of claim 34, wherein the first set of transformation parameters represents a first five degrees of freedom, and the second set of transformation parameters represents a second five degrees of freedom, at least one of the first five degrees of freedom overlapping one of the second five degrees of freedom, and wherein the combined set of six 3D transformation parameters represent six degrees of freedom.

36. (New) The method of claim 33, wherein each of the first set of 2D images and the second set of 2D images correspond to perturbations from said initial position along at most two degrees of freedom.

37. (New) The method of claim 36, wherein the first set of 2D images corresponds to out of plane rotations for a first plane of the first x-ray image and the second set of 2D images corresponds to out of plane rotations for a second plane of the second x-ray image.

38. (New) The method of claim 37, wherein one of the out of plane rotations for the first plane is an in plane rotation for the second plane.